FIG. **5** is a side view of a clamp on sensor attached to a pipeline.

FIG. **6** is a sectional view of the FIG. **5** sensor.

FIG. **7** is an exemplary plot of echo magnitude versus time illustrating echoes **1–5** of a representative diminishing series of echo amplitudes.

FIG. **8** is an exemplary plot of log echo amplitude versus echo number with a straight line fit to the exemplary data.

DETAILED DESCRIPTION

For the purpose of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended. Any alterations and further modifications in the described embodiments, and any further applications of the principles of the invention as described herein are contemplated as would normally occur to one skilled in the art to which the invention relates.

Turning now to FIG. **1**, a system **20** for analyzing a property of fluid **25** is depicted. Fluid **25** can be a gas, liquid, slurry, suspension, paste, emulsion and the like. In preferred forms, fluid **25** is substantially non gasseous and/or includes at least one liquid. In this form, fluid **25** might be, for example, a liquid, slurry, or suspension. In further preferred forms fluid **25** has a viscosity greater than about 0.5 cP and/or a density greater than about 0.3 g/cm^3.

Ultrasonic transducer **30** is acoustically coupled to a first surface **42** of a member **40** comprised of a solid material. In one example, transducer **30** is in direct contact with member **40**. In other examples, one or more couplants might be used between transducer **30** and member **40**, or they may be coupled as would otherwise occur to those skilled in the art. An opposed second surface **44** of member **40** is in contact with the fluid **25**. A pulser **22** is electrically coupled to transducer **30** and is operable to deliver input stimulus signal to transducer **30** to cause transducer **30** to emit acoustic energy through solid member **40** and towards fluid **25**. Transducer **30** is also operable to produce output signals in response to acoustic energy transmitted from member **40**. A processing apparatus **22** including receiver **60**, digitizer **70**, and computer **80**, is coupled to pulser **22** and to transducer **30**. Processing apparatus **22** controls delivery of the transducer input signals, receives the output signals from transducer **30**, and, as described more fully below, performs calculations to determine properties of fluid **25** as a function of the transducer output signals.

In operation, pulser **50** generates and delivers a short duration stimulus to transducer **30**. Transducer **30** responds to the stimulus by emitting a longitudinal wave pulse of ultrasound into member **40**. This ultrasonic pulse reflects between surfaces **44** and **42** producing a series of pulse echoes at transducer **30**. This resulting echo series will be of successively diminishing echo amplitude because each successive echo will have reflected from the solid fluid interface at surface **44** one time more than the previous echo. An exemplary plot of echo magnitude versus time after the initial pulse, illustrating echoes **1–5** of a diminishing series of echoes, is shown in FIG. **7**.

Transducer **30** responds to the echoes by producing an output signal proportional to the echo amplitude that is amplified by receiver **60**, digitized by digitizer **70** and passed to computer **80**. Computer **80** includes programming instructions encoded on fixed and/or removable memory devices **84**, **86**, respectively, to select a peak echo amplitude for the series echoes and to determine the average decay rate of the peak echo amplitudes with increasing echo number in the echo series. Alternatively, computer **80** can be at least partially hard wired with dedicated memory devices and configured to execute logic according to the present invention. Computer **80** is operatively coupled to display **82** to output selected information about fluid **25** integrated with transducer **30**.

Preferably a number of echo amplitudes, for example 5 or more, spanning a range of echo numbers are used in computing the decay rate. In one preferred form, computer **80** is programmed to first compute the fast Fourier transform (FFT) of the digitized signal, converting it from the time domain to the frequency domain and then determine the peak amplitude at a selected frequency, where the frequency is selected to be, for example, the center frequency of transducer **30**. In a still further preferred form, the process is repeated for a number of pulses from transducer **30**, and the average decay rate of the peak echo amplitudes is determined for each repetition. A rolling average of the resulting set of average decay rates is then determined.

The determined average decay rate can be expressed as the slope of the line of the natural log of echo amplitude versus echo number (ΔF). An exemplary plot of log echo amplitude versus echo number with a line fit to the exemplary data is shown in FIG. **8**. Utilizing this expression of the average decay rate, computer **80** calculates the reflection coefficient for the fluid-solid interface (RCfluid) according to equation (1)

$$RCfluid/RCcalib=e^{(\Delta F-\Delta C)} \quad (1)$$

where ΔC is the slope of the natural log of echo amplitude versus echo number determined by replacing the fluid **25** with a calibration fluid, and RCcalib is the calculated reflection coefficient for the fluid-solid interface when the fluid is the calibration fluid. The values for RCcalib and ΔC are stored in memory **84** and/or **86**, and the value for RCcalib is calculated in advance according to equation (2)

$$RCcalib=(Zcalib-Zsolid)/(Zcalib+Zsolid) \quad (2)$$

where Zcalib is the acoustic impedance of the calibration fluid and Zsolid is the acoustic impedance of the solid member **40**.

From the fluid specific reflection coefficient (RCfluid), computer **80** calculates the acoustic impedance of the fluid (Zfluid) according to equation (3)

$$Zfluid=Zsolid\ (1-RCfluid)/(1+RCfluid) \quad (3)$$

where Zsolid is the acoustic impedance of the solid member **40**.

From the acoustic impedance of the fluid (Zfluid), computer **80** calculates a physical property of the fluid. The density of the fluid (ρF) is calculated according to equation (4)

$$\rho F=Zfluid/Vfluid \quad (4)$$

where Vfluid is the speed of the sound in the fluid. An indication of the fluid density is then produced on display **82**.

In a preferred form, the speed of sound (Vfluid) is determined by performance of a time-of-flight measurement on the fluid. A time-of-flight measurement is accomplished by measuring the time it takes an ultrasound pulse to travel a known distance through the fluid **25**. The speed of sound (Vfluid) is then determined by dividing the known distance by the determined transit time. FIGS. **2** and **3** schematically illustrate devices **102** and **104** for performing time-of-flight measurements that can form a portion of system **20**. In the FIG. **2** embodiment, a pair of transducers **110, 112** are arranged in pitch-catch mode and measure the time it takes